Volkswagen Cabriolet DIY Guide

K-Jetronic: Measuring Duty Cycle, Adjusting Air-Fuel Mixture, & Setting Idle

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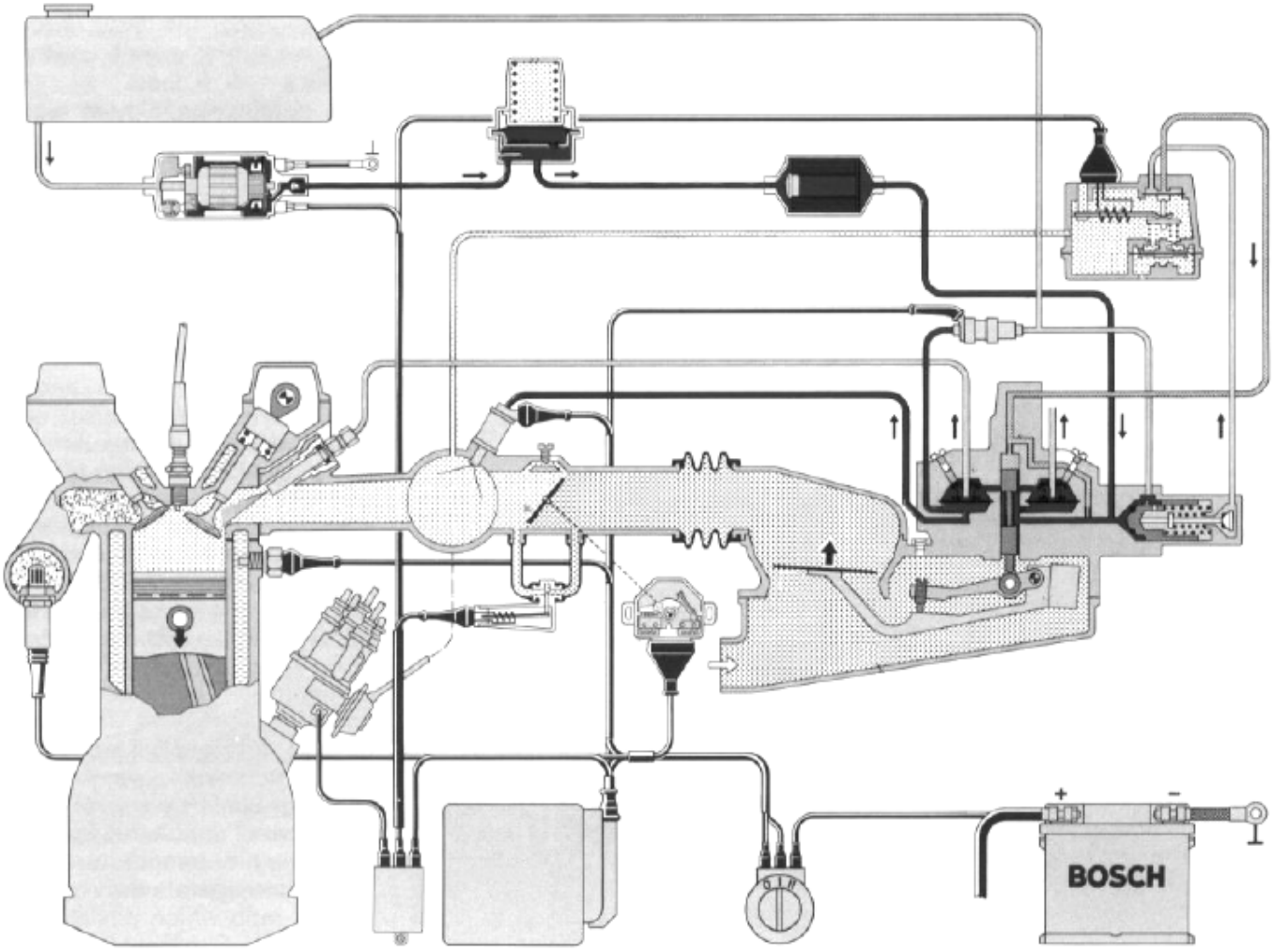

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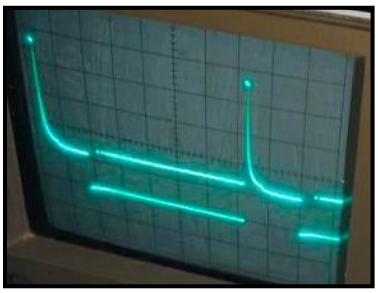
Overview of The System

Before doing anything, let's discuss what CIS, K-Jetronic, lambda, and duty cycle are so that you get a very basic understanding of how the system works and what it is you'll be testing.

K-Jetronic is a mechanical fuel injection system developed by Bosch in the 1970s and is used in a wide variety of vehicles around the world. K-Jetronic is a **c**ontinuous **i**njection **s**ystem (CIS), which means that the fuel injectors receive and produce a constant flow of fuel, provided there is proper pressure, whenever the engine is running. K-Jetronic is a mechanical injection system because fuel is metered by the mechanical link between the fuel distributor and airflow sensor plate, which are linked together in one housing. In other words, fuel is metered in proportion to the incoming air flow.

In order to adhere to stricter emissions requirements in North America, Bosch enhanced K-Jetronic by adding lambda control. With the addition of an oxygen sensor (aka lambda probe) feedback system, K-Jetronic's air-fuel mixture can be more precisely controlled while the engine is running under various conditions (cold, warm, full-throttle). K-lambda (as it's often referred to) has better emissions, in theory, than its basic predecessor. It is called lambda because Bosch uses the Greek letter *lambda* (λ) to represent the stoichiometric ratio (14.7:1) of the air-fuel mixture the system strives to achieve for peak operating performance.



Photos by Myndex (l.) and Walt Fricke (r.) from benzworld.org forum.

When the engine is warmed up, the oxygen sensor produces an electrical signal based on the oxygen content in the exhaust that is sent to the Jetronic control unit under the dash. This control unit takes the oxygen sensor's voltage, converts it to a square wave signal (a pulsed 100 Hz on/off ground signal), and sends that signal to the frequency valve (aka lambda valve, an injector of sorts), which determines the amount of time the valve is open. That pulsed ground signal is the lambda system's duty cycle. The valve's on/off behavior is what creates the audible buzzing (reminder: if the frequency valve does **not** buzz/vibrate, there is something wrong). Note: The frequency valve does **not** *meter* fuel, but, rather, controls the fuel distributor's lower chamber fuel pressure, which, in turn, changes upper chamber pressure to vary fuel enrichment. The photos above show two lambda system duty cycles as produced by oscilloscopes. The left photo depicts a system that is being enriched while the vehicle is being driven; the right photo shows a system at approximately 50%.

Photo by Myndex from benzworld.org forum.

While it is often called an electronic control unit, the Jetronic controller is **not** a computer and should never be referred to as such. Because this control unit is analog and merely processes and reroutes voltage signals, it is very wrong to refer to K-lambda as an electronic fuel system… it is **not** an electronic fuel system! While the frequency valve operates based on an electronic voltage signal, the air-fuel mixture still takes place *mechanically* inside the fuel distributor as described above. The K-Jetronic lambda controller installed in Volkswagen Cabriolets (and Rabbits, Golfs, Sciroccos, and a host of other vehicles) consists of nothing more than a circuit board with a bunch of capacitors, inductors, resistors, transistors, and diodes. As you can see from the photo at left, the controller is really nothing more than a relay (of sorts) on steroids.

The basic stages of the lambda system:

1. Open loop - cold: Engine is cold-started, thus providing cold-running enrichment during warm-up period.
2. Open loop - warm: Cold enrichment has ended; system is at 50% duty cycle, waiting for oxygen sensor activity; also known as limp-home mode.
3. Closed loop: Oxygen sensor is sufficiently heated and is now sending voltage signals to control unit during the engine's warm running period.
4. Open loop - WOT: Full-throttle (aka **w**ide-**o**pen **t**hrottle) switch has been activated, providing fuel enrichment override.

While the pulsed ground signal sent from the oxygen sensor control unit to the frequency valve is a square wave valued on a 100 Hertz (Hz) frequency scale (with spikes up to 12,000), this voltage signal is measured in duty cycle (0-100%), or in dwell (0-90°). This information is used to adjust, if need be, the air-fuel mixture on a K-lambda car.

Here's how the system works (provided everything is functioning as it should):

1. If you start the car when the engine temperature is cold, the normally closed oxygen sensor thermoswitch completes the ground signal to the control unit.
2. The control unit sends a fixed 80% duty cycle (65% for 1988+) signal to the frequency valve. That fixed cold-running enrichment signal (80% or 65%) remains in place until the coolant reaches a specific temperature (25°C or 45°C, depending on the thermoswitch installed in your car).
3. The thermoswitch then opens, cutting its signal to the control unit. If the oxygen sensor is not at its operating temperature when the thermoswitch opens, the system reverts to warm open loop, or limp-home mode (50%).
4. Once the oxygen sensor is heated to its proper temperature, it sends a signal to the control unit and the system enters closed loop, or its normal regulating function (50% ±8% duty cycle). Should the full-throttle switch be activated, closed-loop is overridden for forced full-throttle enrichment (65% duty cycle).

Up to June 1987, cold-running enrichment (80%) overrides full-throttle enrichment (65%). From July 1987 onward, cold-running enrichment does not override full-throttle enrichment because the two values are the same (65%).

> "Open loop will also happen when the car has been parked briefly, the oxygen sensor has cooled off, and the thermoswitch hasn't closed; upon restarting, it takes a minute or more before the oxygen sensor heats enough to produce a signal and send the system into closed loop. That's why oxygen sensors are now heated; they start working faster, systems go into closed-loop sooner.
>
> "There isn't always an open-loop stage during warm-up. If the engine is cold (real cold, like winter in Montana cold), and the oxygen sensor is in great shape, the oxygen sensor's heater and the exhaust heat may get the oxygen sensor up to operating temperature before the thermoswitch warms enough from from the coolant to open. In that sort of circumstance, the system will go straight from cold-running enrichment to closed-loop; no open-loop transition at all. Same car, same cold weather: The oxygen sensor will cool quickly when the car is parked, while the coolant will retain heat much longer; on restart, there will be no cold-running enrichment -- the system will be in open-loop until the oxygen sensor warms up enough to put the system into closed-loop." ~tolusina of VWvortex.com

Likewise, if the car is in a warm climate (or during warm seasonal months), the system may revert to open loop upon initial start-up, skipping cold-running enrichment due to the coolant already being at or above the thermoswitch's pre-set temperature.

The preceding is only a very brief overview of how K-lambda operates. For much more detail on the theory, application, component descriptions, performance, modifications, and troubleshooting, please obtain Charles Probst's book, *Bosch Fuel Injection & Engine Management*.

The Required Meter

In order to read your lambda system's duty cycle, you need a digital or analog meter that can read duty cycle (%) and/or dwell. A simple volt-ohm meter will **not** do the job. This is also a case of "you get what you pay for". While you can visit Harbor Freight with your 20% off coupon, the quality of meters they sell is substandard and there are numerous reports of inaccuracy. You don't need the most expensive meter on the market, but you want *quality*. Additionally, while you can use a dwell meter, it has been reported that using a dwell meter does not provide quite as accurate of a reading as a duty cycle meter, but it gets close enough. If you already have a dwell meter, go ahead and use it; if you are new to the game, try to find a duty cycle meter (or better, a meter that has both for additional automotive troubleshooting).

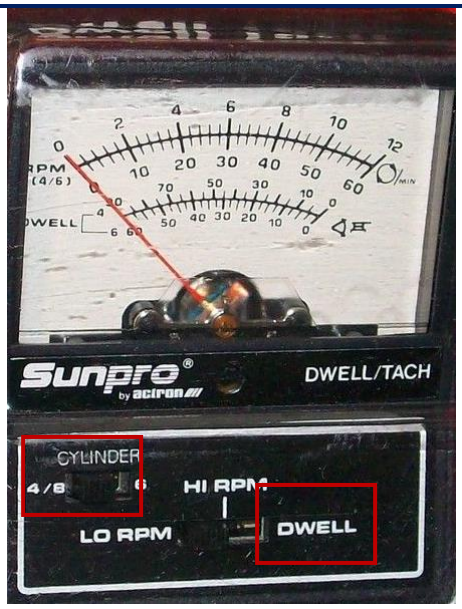
An oscilloscope, like those on page one, is actually the best and most accurate device for this job, but it is not a multifunction tool for your toolbox. There is no need to buy this type of instrument just to read your car's duty cycle, unless you wish to have a neat toy to play with.

So, what do you look for? Example meters are on the following page. Remember, these are merely examples highlighting what setting your perspective meter should have in order to read your lambda system's duty cycle. I.E. these meters are not necessarily being recommended (for the record I, personally, use a Craftsman duty cycle meter that is, ironically, not shown in the examples).

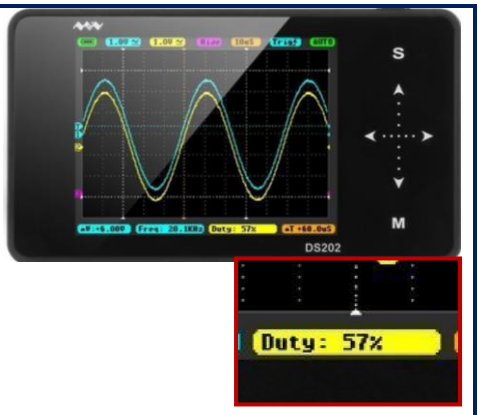
Meter Examples

If buying a duty cycle meter, the meter **MUST** have the ability to switch to %/duty (note: some meters read only AC voltage duty cycle). Otherwise, you will be measuring Hertz (Hz), which is not included in these instructions.

Your digital dwell meter **must** have a 4 cylinder setting.



Be sure to read your analog meter's manual. Some meters require you to double the 8-cylinder reading, others require you to divide by 2, if they do not have a separate 4-cylinder gauge.



The above is a modern digital, portable oscilloscope that not only graphs the signal, but provides the actual duty cycle number on the screen, which is very handy when needing to make fine adjustments of the air-fuel mix. An oscilloscope is a neat tool to play with, especially for visual, scientific-types, but it's a tool that will go largely unused for most DIY home mechanics. Fun device that is the most accurate, but it's certainly not necessary to have.

Before Checking Duty Cycle & Making Adjustments

Requirements:

- ✓ Car should be otherwise well-tuned (see below for further information)
- ✓ No, and I mean zero, vacuum leaks
- ✓ Distributor advance mechanism(s) should be operating correctly
- ✓ Timing should be correctly set with a closed throttle plate
- ✓ Air-fuel mixture plug removed and mixture screw free of gunk
- ✓ Frequency valve **should be** buzzing/vibrating whenever the fuel pumps are running; if it is **not** buzzing, please test it.

Start with a complete tune up (if not recently conducted):

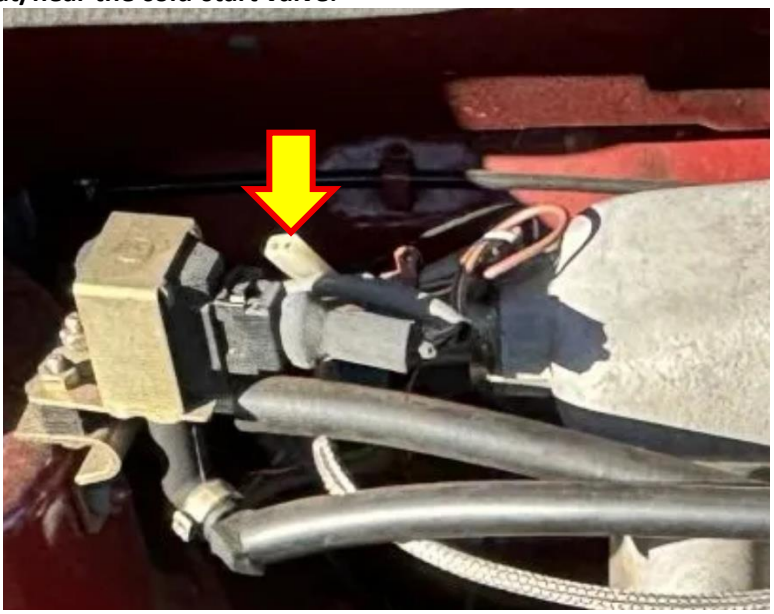
- ✓ Replace ignition components: spark plugs, cap, rotor, wires (use Bosch ignition parts and use NGK plugs)
- ✓ Replace air and fuel filters
- ✓ Replace injector seals and idle screw O-ring
- ✓ Tighten the injector holders; replace the injector holders, if needed
- ✓ Check for vacuum leaks using carburetor cleaner (spray around hoses, gaskets, injector O-rings); if idle goes up, leak found (replace faulty part -- use a bit of RTV when replacing gaskets)
- ✓ Check your K-Jetronic grounds at the cold-start valve: they should be clean, fully connected, and intact
- ✓ Test your oxygen sensor (pages 9-10) and replace, if need be
- ✓ Check your full-throttle switch and idle boost valve(s)
- ✓ Check your K-Jetronic system and control pressures
- ✓ Check your distributor's centrifugal and vacuum advance mechanisms
- ✓ Set your timing, if need be

⚠ Do **NOT**, under any circumstances, disassemble the fuel distributor and/or airflow sensor unless you know for certain what you're doing! Taking this piece of precision equipment apart on a whim because your K-Jetronic fuel injection system is not running right is a disaster waiting to happen, and usually ends with you having to buy a new (actually used/rebuilt) fuel distributor!

If you feel that you and your car are prepared for testing, proceed to the next section.

Test Connector

Factory-original connector at/near the cold-start valve:



Replacement connector options (requires cutting off original connector):

Insulated spade terminals

Home-made harness: EV1 connector to meter test leads

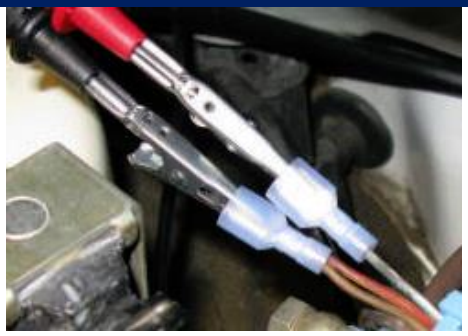
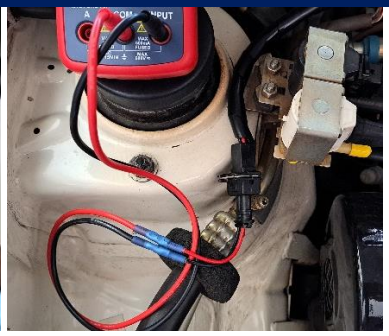
Checking Duty Cycle & Making Adjustments

Tools needed:

- ✓ Volt-ohm meter that measures duty cycle (dwell meter can also be used, but duty cycle is a bit more accurate)
- ✓ 3mm Allen wrench (T-handle version advised)
- ✓ 7mm crescent wrench

Duty cycle = 0-100% | **Dwell** = 0-90° scale (45° dwell = 50% duty cycle).

Step 1: Connect meter

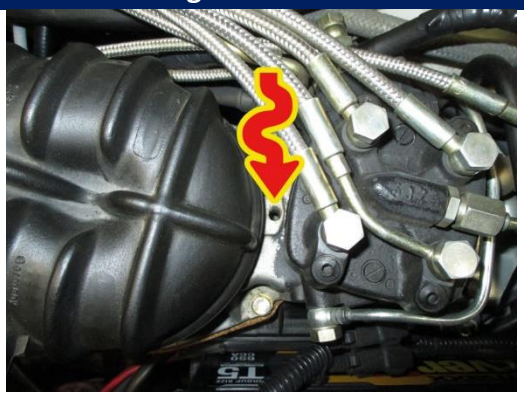



- Connect the red positive (+) meter wire to the test connector's blue/white wire's terminal; connect the black negative (-) meter wire to the test connector's brown wires' terminal.
- If using the dwell setting, set meter to "4 cyl";
- If using the duty cycle setting, set meter to "frequency %" **

Read your meter's instructions; some meters require an additional step, such as pressing a button such as "range".

If using duty cycle, be aware that Cabriolets produce a **negative slope reading. Many meters read only in positive slope. Easy test: Connect the test leads as described. With the engine running, actuate the full-throttle switch. If the reading is 35%, reverse the test leads: red (+) to brown wire, black (-) to blue/white wire. Actuate the full-throttle switch once more; the reading should be 65%.

Step 2: Warm the engine



Run the engine up to operating temperature (oil at 80°C); the cooling fan should cycle on/off at least once. Keep all accessories off.

Make note of where the air-fuel adjustment screw is on the airflow sensor (do **not** put the Allen wrench in the hole until you adjust the mixture!!). Note: The factory anti-tamper plug must be removed first! Please click here for details on removal.

Step 3: Read your meter

Target reading:

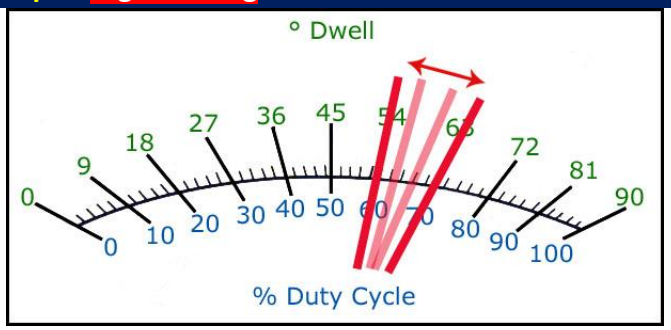
Duty Cycle	Dwell
50% (±8%)	45° (±7°)

✅ If it **is** within this range, skip to Step 5.

❎ If it is **not** within this range, continue to Step 4.

Note: If the reading bounce/swing is higher than a range of 10 (ex. 55-74), there are issues that need resolving before continuing.

Step 4: High reading



Lean setting, rich correction

Your air-fuel mixture setting is too lean and the control unit is making a rich correction.

Check for vacuum/air leaks; fix any that are found.

Insert your 3mm Allen wrench into the adjustment hole and **turn the wrench clockwise**. You are richening up a lean condition.

Step 4: Low reading

Rich setting, lean correction

Your air-fuel mixture setting is too rich and the control unit is making a lean correction.

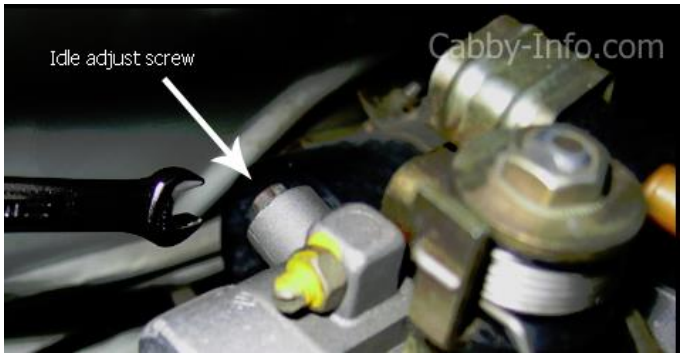
Check cold-start valve to verify that it is not leaking.

Insert your 3mm Allen wrench into the adjustment hole and **turn the wrench counterclockwise**. You are leaning out a rich condition.

NOTE: The weight of the wrench will affect the mixture! Turn the wrench a little, just enough to feel it move, then lift the wrench out of the adjustment screw hole. Repeat this process until 45° ±7° dwell / 50% ±8% duty cycle is achieved.

Step 5: Idle adjustment

Have your 7mm open-end wrench handy; you **may** have to tweak the idle bypass screw (backside of the throttle body) if the idle changes too much after adjusting the mixture. You need to stay below about 900 RPM while adjusting the idle. Use the tach on the dash and your ears, you know what sounds right and normal. If you go over 900 RPM, the centrifugal advance starts to kick in, changing the timing and confusing all your readings. Set the idle RPM at 900±, but above the threshold of the idle boost valve.



If the idle boost valve kicks in while you are adjusting, you've dropped too low on idle RPM. You can unplug the idle boost valve electrical connector, or better, pinch off either of the hoses going to it. When the idle boost valve (or hose) is reconnected, idle should not change if you've adjusted the idle correctly.

Switch on the A/C (if installed) to make sure that the A/C idle boost valve works; idle should stay about the same with the A/C compressor running.

Notes: 1987-1989 with cold-running enrichment system

"I had the fuel pump go on me and replaced it with a Bosch original OEM that has the threaded Check Valve screwed into the top of it. While I was there I replaced the Accumulator as well seeing as it was all rusty and original and more than likely due soon for replacement.

Upon replacing these 2 parts the engine would run great and start fine cold. So well in-fact that I equipped the car with a Remote Starter unit. The problem was that when the car was hot (Oil temperature between 80ºC - 100ºC) and had been sitting for 10, 15 or 20 minutes the car would be almost impossible to start or would start and studder like crazy and require you to step on the accelerator to clear it up.

My dad (mechanic of 35 years) and I spent days trying to remedy this problem and drove ourselves nuts. We checked fuel pressures, we checked the warm up regulator, the cold start valve (also used in hot-restart). The relays and control modules, the thermo time switch and the list goes on and on.

We found out that the Dwell of 45º that is listed on this site and others my not apply to all models. What we did was rev the engine to 2,000rpm and set the idle-mixture screw until the dwell fell to 45º at this RPM. Then it would naturally enrichen the mixture when the idle was allowed to fall to the 925 ±25 rpm as indicated on the hood sticker. It was only then that the car would start/restart properly under hot conditions.

I wanted to share this information with you to help anyone else banging their head against the wall like we did trying to get it to start properly when hot with this Hot-Pulse Start system.

Please note that we checked all cold/hot fuel pressures and residual pressures on shut-down both cold/hot and they were within spec. The car also has brand new injectors, thermo-time switch, fuel pump, accumulator, filter, air-filter, cap/rotor, spark-plugs, spark-plug wires, vacuum enrichment switch, Oxygen Sensor, idle-stabilizer relay, fuel pump relay, Hot-Pulse Start Relay. As we replaced all this trying to remedy this problem. So we know that this is the setting that it should be at."

~ Steve C.

Ed. Note: This remedy is abnormal/unusual, but worked for this particular car when all other remedies were exhausted. It is being included in case someone happens to encounters the same issue.

Notes ~ Questionable readings

Should you find questionable meter operation while measuring frequency valve duty cycle (ex., the reading never changes):

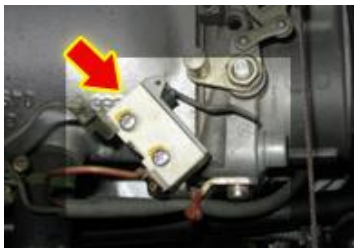
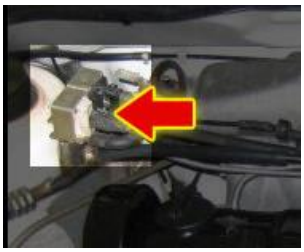
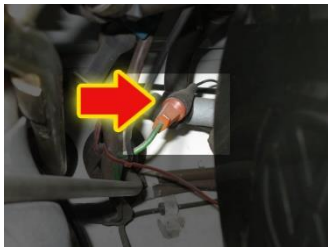
- Connect your test lead to the Hall sender green/white wire and test your meter. It should read a very steady 36-37° on the 4 cylinder dwell scale, 40.5-40.6% duty cycle.
- If the meter proves to be good:
  - ✓ Conduct the tests in the lambda system testing section starting on page 8.
  - ✓ The test port connector itself could be faulty. Refer to the Test Port section on page 12.

Lambda System Testing

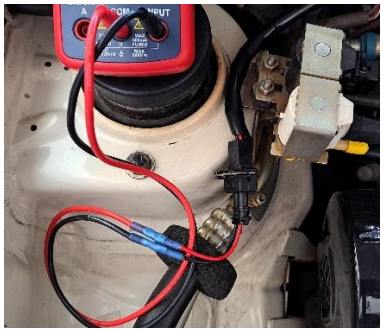
Tools needed:

- ✓ Volt-ohm meter that measures duty cycle (dwell meter can also be used)
- ✓ Hose pinchers
- ✓ New D-cell battery
- ✓ Jumper wire using two male spade connectors
- ✓ Test tables on page 11 and a pen(cil)

Location of components referred to in this section (1.8L):

Oxygen Sensor Thermoswitch Underside of coolant hose flange	 **Full-throttle (WOT) Switch** At front of throttle body	 **Idle Boost Valve(s)** Right strut tower
Cold-running Enrichment Vcauum Switch In front of intake manifold	 **Oxygen Sensor Connector** Near the firewall, right side of engine bay	

Step 1: Connect Meter



Connect your meter according to the Step 1 instructions on page 7.

Test 1: Cold Running Enrichment 1980-1987

Target reading:

Duty Cycle	Dwell
80% with little fluctuation	72° with little fluctuation

Open Loop - cold

1. Disconnect the leads from the oxygen sensor thermoswitch and bridge the terminals using a jumper wire with male spade terminals.
2. Start and run the engine.

Test 1: Cold Running Enrichment 1988+

Target reading:

Duty Cycle	Dwell
65% with little fluctuation	58° with little fluctuation

Open Loop - cold

1. Disconnect the leads from the oxygen sensor thermoswitch and bridge the terminals using a jumper wire with male spade terminals.
2. Start and run the engine.

Disconnect the oxygen sensor after doing the above test. Your meter should read 65% duty cycle (or 58° dwell) with very little fluctuation. If the meter reads 50% (or 45°), check the cold-running enrichment vacuum switch. Reconnect the oxygen sensor before continuing.

Test 2: Limp-home Mode ALL

Target reading:

Duty Cycle	Dwell
50% with little fluctuation	45° with little fluctuation

Open Loop - warm

1. Leave the engine running.
2. Disconnect your jumper wire from Test 1 and leave the thermoswitch disconnected.
3. If the engine is at operating temperature by now, disconnect oxygen sensor.

Test 3: Full-throttle enrichment 1.8L

Target reading:

Duty Cycle	Dwell
65% (±2%)	58.5° (±2°)

Open Loop - WOT

1. Leave the engine running.
2. Leave the oxygen sensor thermoswitch disconnected and unbridged.
3. Actuate the full-throttle switch.

Cars fitted with Callaway turbo: see notes on page 16.

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Test 4: Warm Running ALL

Target reading:

Duty Cycle	Dwell
50% steady to ±8% fluctuation	45° steady to ±7° fluctuation

Closed Loop

1. Leave the engine running and ensure it is at operating temperature.
2. Reconnect oxygen sensor and the oxygen sensor thermoswitch while keeping an eye on your meter.

You should see the reading change from constant to fluctuating. If the meter is already fluctuating when you connect the thermoswitch, turn the engine off, let it cool down for a bit and retry this test.

Test 5: Rich Correction ALL

Target reading:

Duty Cycle	Dwell
87% and rising	78° and rising

Lean Condition, Rich Correction

1. Disconnect the leads from the oxygen sensor thermoswitch (do **not** bridge/jump them).
2. Disconnect the black oxygen sensor wire from the green control unit wire.
3. Run the engine (if you've shut it off).
4. Ground the green wire's spade terminal on bare metal (use a jumper wire if need be).

Test 6: Lean Correction ALL

Target reading:

Duty Cycle	Dwell
20% and falling	18° and falling

Rich Condition, Lean Correction

1. Keep the engine running and the wires in Step 5 disconnected.
2. Ground the negative end of the D-cell battery while touching the oxygen sensor control unit's green wire spade terminal to the positive end of the D-cell battery.

Note: Engine may stall; this is normal.

Test 7: Oxygen Sensor method 1

1. Start the engine and let it run until it reaches operating temperature (80°C or higher); if it's already warm, let it run for two minutes.
2. Clamp off the hose from the idle speed boost valve (white valve, if your car has A/C).
3. Disconnect the crankcase ventilation hose.
4. Make note of the duty cycle reading.
5. Plug the crankcase ventilation hose. The duty cycle should drop, then rise and fluctuate.
6. If the duty cycle does not drop, then rise and fluctuate, the oxygen sensor is faulty.

Test 7 ~ Oxygen Sensor method 2

1. Start the engine and let it run until it reaches operating temperature (80°C or higher); if it's already warm, let it run for two minutes.
2. Disconnect the oxygen sensor wire (black) from the oxygen sensor control unit wire (green).
    - If you have two DVOMs, you can connect the second one as shown in Step 1 to read the duty cycle/dwell at the same time, but this is not necessary.
3. Connect the black DVOM lead to any convenient ground and connect the red DVOM lead to the oxygen sensor lead wire (black).
4. Set the DVOM dial to 2 DCV (or 4 DCV, if that's the lowest setting on your meter).
5. Ground the oxygen sensor control unit lead wire to bare metal to simulate a lean condition. The oxygen sensor's voltage should go high: 0.8 to 1.0 DCV
    - Duty cycle/dwell should go high, 85%/75° or higher.
6. Connect the D-cell battery's positive end to the green oxygen control unit lead wire and ground the negative end of the battery against bare metal; this simulates a very rich condition. The oxygen sensor's voltage should go low: 0.15 DCV or lower
    - Duty cycle/dwell should go very low, 10%/9°.
    - Note: The system may go so lean that the engine stalls; this is normal.
7. Keep the engine running and leave the meter's black lead connected to ground, but connect the meter's red lead to the green ECU (aka Vref) wire. You should see a steady 0.45 DCV to 0.50 DCV. Flex the green ECU wire; if voltage drops to or near zero there is most likely a short in the green ECU cable that needs to be repaired.

What you are measuring in Step 7 above is Vref, or reference voltage:

This Vref is pretty much the heart of this (or any, really) 'closed loop' mixture control system. The ECU sets a steady reference voltage of 0.45 VDC to 0.50 VDC (this voltage is steady, varies slightly between different ECUs) on the green oxygen sensor wire, the black O_2 sensor lead connects to this wire.

The oxygen sensor, once at operating temperature, outputs a voltage between approximately 0.1 VDC (a lean signal), to approximately 0.9 VDC (a rich signal).

When the ECU sees an oxygen sensor voltage higher than its Vref, it correctly interprets that to mean that the mixture is richer than stoichiometric (i.e. 14.7:1 air-fuel ratio), the ECU then leans the mixture to compensate by lowering the duty cycle to the frequency valve below 50%. Once below 50%, it is now too lean; oxygen sensor voltage is now below Vref, so duty cycle goes back up to correct.

On and on goes this continuous correction, the ECU constantly trying and failing to get the oxygen sensor voltage to match Vref. The system is actually designed to strive and fail. There are two reasons it strives and fails. One is built in response delays, the other is that those response delays are built in so that the catalytic converter will always have a slightly fluctuating mixture, something the cat converter requires for its chemical reaction to work properly.

above information provided by *tolusina* of VWvortex

Notes

- A sluggish oxygen sensor may cause a failed smog inspection while exhibiting absolutely no other drivability issues.

- Should you see an operating range at the oxygen sensor ranging from -0.5 DCV to 0 DCV (instead of the normal +0.1 DCV to +0.9 DCV), your sensor has been permanently damaged by chemical contamination and needs replacing. You may also experience a constant, very high duty cycle reading, like 96% during duty cycle check.

- Cabriolets built from July 1987 through 1989 have heated (3-wire) oxygen sensors. Should you see 12 DCV (or charging voltage) at the oxygen sensor wire, replace the oxygen sensor immediately -- the heater has shorted to the sensor.

- Should the oxygen sensor control unit happen to be faulty, it will fail to compensate for the simulated lean/rich conditions described above. The oxygen sensor control unit rarely goes bad, but is does happen. Before condemning the control unit as being faulty, verify that the control unit is receiving power (pin-out diagram on page 15) and that all ground wires/connections are good. Additionally, if the duty cycle stays at 65% or 80%, disconnect the cold running enrichment switch (if installed) and the full-throttle switch, one at a time, then both together if need be.

Lambda System Condition Simulation Testing Tables

These tests can help determine which components may be faulty & are a condensed version of pages 10-12.

1980-1987 **without** cold-running enrichment system

Test	Oxygen Sensor	Full-throttle Switch	Oxygen Sensor Thermoswitch	Running Stage	Reading Should Be…	Your Reading
1 Open Loop - cold	Connected	Connected	Disconnected, leads bridged	Cold-running enrichment	**80% (±2%)** 72° (±2°)	
2 Open Loop - warm	Disconnected	Connected	Disconnected	Limp-home mode	**50% (±2%)** 45° (±2°)	
3 Open Loop - WOT	Connected	Connected & Actuated	Disconnected	Full-throttle enrichment	**65% (±2%)** 58.5° (±2°)	
4 Closed Loop	Connected	Connected	Connected	Warm running	**50% (±8%)** 45° (±7°)	
5 Rich Correction	Disconnected, ECU lead grounded	Connected	Disconnected	Lean condition, rich correction	**87%** (increasing) 78.3° (increasing)	
6 Lean Correction	Disconnected, +1.5V applied to ECU lead, -1.5V grounded	Connected	Disconnected	Rich condition, lean correction	**20%** (decreasing) 18° (decreasing)	

Test 6 requires a D-cell battery; ECU lead wire is green. Test 6 may lead to engine stall (this is normal).

These are simulation tests; being at operating temp is unnecessary for all tests except 4.

Reminder: Duty cycle readings are in negative slope %… be sure your % meter leads are connected properly.

July 1987 – 1993 **with** cold-running enrichment system								
Test	**Oxygen Sensor**	**Full-throttle Switch**	**Oxygen Sensor Thermoswitch**	**Cold-running Vacuum Switch**	**Running Stage**	**Reading Should Be…**	**Your Reading**	**If Reading Is…**
1a Open Loop - cold	Connected	Connected	Disconnected, brown/red wire grounded		Cold-running enrichment	**65% (±2%)** 58.5° (±2°)		
1b Open Loop - cold	Disconnected	Connected	Disconnected, leads bridged		Cold-running enrichment	**65% (±2%)** 58.5° (±2°)		**50%/**45°, go to tests 1c & 1d
1c	Disconnected	Connected	Disconnected, leads bridged	Harness disconnected, Vacuum hose Connected	Limp-home mode	**50% (±2%)** 45° (±2°)		not within spec, go to test 1e
1d	Disconnected	Connected	Disconnected, leads bridged	Harness connected, Vacuum hose disconnected	Limp-home mode	**50% (±2%)** 45° (±2°)		
1e*	Connected	Connected	Disconnected, leads bridged	Harness connected, Vacuum hose Connected	Cold-running enrichment	**65% (±2%)** 58.5° (±2°) while cranking		50%/45°, check cold-start relay & wiring
2 Open Loop - warm	Disconnected	Connected	Disconnected		Limp-home mode	**50% (±2%)** 45° (±2°)		
3 Open Loop - WOT	Connected	Connected & Actuated	Disconnected		Full-throttle enrichment	**65% (±2%)** 58.5° (±2°)		
4 Closed Loop	Connected	Connected	Connected		Warm running	**50% (±8%)** 45° (±7°)		
5 Rich Correction	Disconnected, ECU lead grounded	Connected	Disconnected		Lean condition, rich correction	**87%** (increasing) 78.3° (increasing)		
6 Lean Correction	Disconnected, +1.5V applied to ECU lead, -1.5V grounded	Connected	Disconnected		Rich condition, lean correction	**20%** (decreasing) 18° (decreasing)		

*** 1e**: Engine off. Disconnect coil wire from distributor cap and ground it with jumper wire. Actuate starter.

Test 6 requires a D-cell battery; ECU lead wire is green. Test 6 may lead to engine stall (this is normal).

These are simulation tests; being at operating temp is unnecessary for all tests except 4.

Reminder: Duty cycle readings are in negative slope %… be sure your % meter leads are connected properly.

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Callaway Turbo Kit – lambda system notes

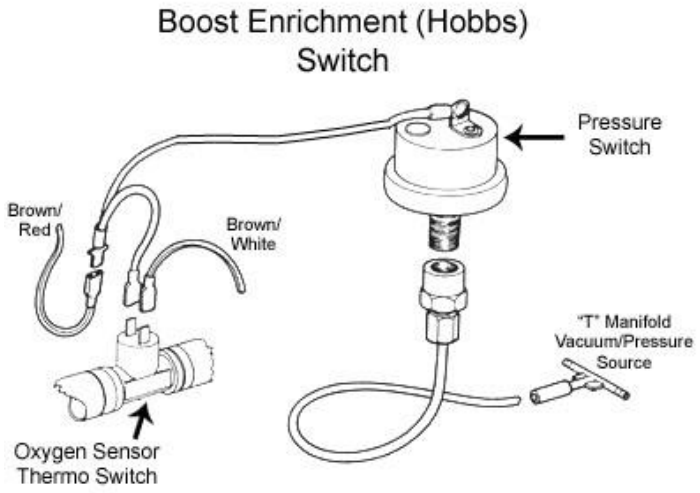
If your car has a Callaway turbo kit installed, it could have one of two scenarios:

1. The WOT switch **may** have been disconnected, or removed altogether.
2. There may be a Hobbs (aka boost enrichment) switch installed in place of the WOT switch, which taps into the O2 sensor thermo switch wiring for 80% enrichment (up through '87), or 65% enrichment (from '88 onward) at a set boost/vacuum pressure (psi).

If your car falls under scenario #1, and your car still has the switch and its wiring, you'll want to reconnect the WOT switch. If the WOT switch is missing, but the wires are still present, bridge the two WOT wires together for Test #3 in the preceding tables (be sure to disconnect the bridge after the test).

If your car falls under scenario #2, you'll want to verify that your Hobbs switch and related vacuum connections are leak-free and that the switch is still operating properly. Because the Hobbs switch takes the place of the factory WOT switch and uses the O2 sensor thermo switch wiring for the enrichment signal (i.e., Test #1) during times of boost, you'll simply ignore Test #3 in the preceding tables.

Your car may also have a micro-fueler, but it operates independent of the K-Jetronic ECU and frequency valve. Thus, it should play no part in testing and adjusting the lambda system.



Source: https://forums.vwvortex.com/showthread.php?6936213-7-years-and-a-Callaway-GTI-later/page8

Test Port & Whacky Readings

If your meter is giving you odd readings and you have verified that the meter is working properly, the test port may be faulty as evidenced by my own experience:

The first two tables below contain readings on my 1986 K-Jetronic-lambda Cabriolet. The initial test readings in attempts 1 and 2 point to a possible control unit issue and/or meter issue (one reason a new meter was bought). However, the tests prove that while the readings are bizarre, the idle changed as did the meter readings, which indicates the control unit is good as well as the meters (meters were double-checked using the green/white Hall generator wire). The thermoswitch was proven good after conducting a resistance test. The frequency valve buzzes every time the engine runs and the engine purrs like a kitten. The components as well as the meters all indicated that everything was A-Okay. So, in the name of science...

Hypothesis: Test port is faulty, which was suspected at the very start.

Attempt #1 (dwell meter)

Test	Oxygen Sensor	Full-throttle Switch	Oxygen Sensor Thermoswitch	Running Stage	Reading Should Be…	My Reading
1 Open Loop - cold	Connected	Connected	Disconnected, leads bridged	Cold-running enrichment	72° (±2°)	84° w/ slight idle drop
2 Open Loop - warm	Connected or Disconnected	Connected	Disconnected	Limp-home mode	45° (±2°)	84°
3 Open Loop - WOT	Connected	Connected & Actuated	Disconnected	Full-throttle enrichment	58.5° (±2°)	84°
4 Closed Loop	Connected	Connected	Connected	Warm running	45° (±7°)	84°
5 Rich Correction	Disconnected, ECU lead grounded	Connected	Disconnected	Lean condition, rich correction	78.3° (increasing)	65° & decreasing
6 Lean Correction	Disconnected, +1.5V applied to ECU lead, -1.5V grounded	Connected	Disconnected	Rich condition, lean correction	18° (decreasing)	42° & decreasing w/ idle drop

Attempt #2 (new duty cycle meter)

Test	Oxygen Sensor	Full-throttle Switch	Oxygen Sensor Thermoswitch	Running Stage	Reading Should Be…	My Reading
1 Open Loop - cold	Connected	Connected	Disconnected, leads bridged	Cold-running enrichment	**80% (±2%)**	89-98%
2 Open Loop - warm	Connected or Disconnected	Connected	Disconnected	Limp-home mode	**50% (±2%)**	70-98%
3 Open Loop - WOT	Connected	Connected & Actuated	Disconnected	Full-throttle enrichment	**65% (±2%)**	90-98%
4 Closed Loop	Connected	Connected	Connected	Warm running	**50% (±8%)**	76-98%
5 Rich Correction	Disconnected, ECU lead grounded	Connected	Disconnected	Lean condition, rich correction	**87%** (increasing)	Rose to 53.7% & stopped
6 Lean Correction	Disconnected, +1.5V applied to ECU lead, -1.5V grounded	Connected	Disconnected	Rich condition, lean correction	**20%** (decreasing)	Dropped to 91.2% w/ idle drop

^Those are some pretty serious whacked-out readings!

Experiment: The factory probe harness was cut off and fully insulated spade terminals were crimped onto the wires in order to provide a better contact using alligator clip adapters on the meter probes.* The tests were then conducted for a third time:

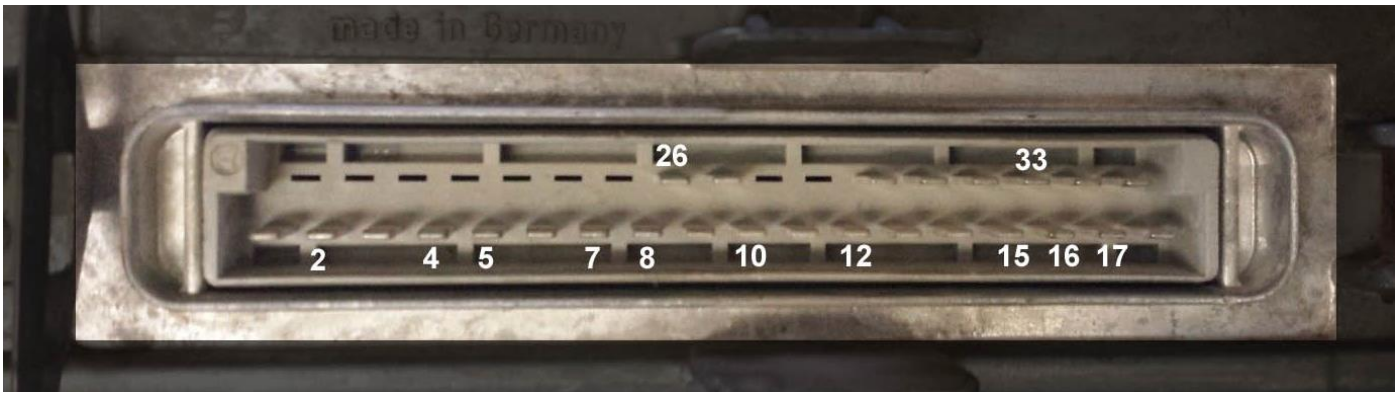
Attempt #3 (new spade test terminals)						
Test	**Oxygen Sensor**	**Full-throttle Switch**	**Oxygen Sensor Thermoswitch**	**Running Stage**	**Reading Should Be…**	**My Reading**
1 Open Loop - cold	Connected	Connected	Disconnected, leads bridged	Cold-running enrichment	**80% (±2%)** 72° (±2°)	80% 67.8°
2 Open Loop - warm	Connected or Disconnected	Connected	Disconnected	Limp-home mode	**50% (±2%)** 45° (±2°)	50% 42°
3 Open Loop - WOT	Connected	Connected & Actuated	Disconnected	Full-throttle enrichment	**65% (±2%)** 58.5° (±2°)	65% 55°
4 Closed Loop	Connected	Connected	Connected	Warm running	**50% (±8%)** 45° (±7°)	85% (running lean)
5 Rich Correction	Disconnected, ECU lead grounded	Connected	Disconnected	Lean condition, rich correction	**87%** (increasing) 78.3° (increasing)	80% + 78.3°+
6 Lean Correction	Disconnected, +1.5V applied to ECU lead, -1.5V grounded	Connected	Disconnected	Rich condition, lean correction	**20%** (decreasing) 18° (decreasing)	Not tested

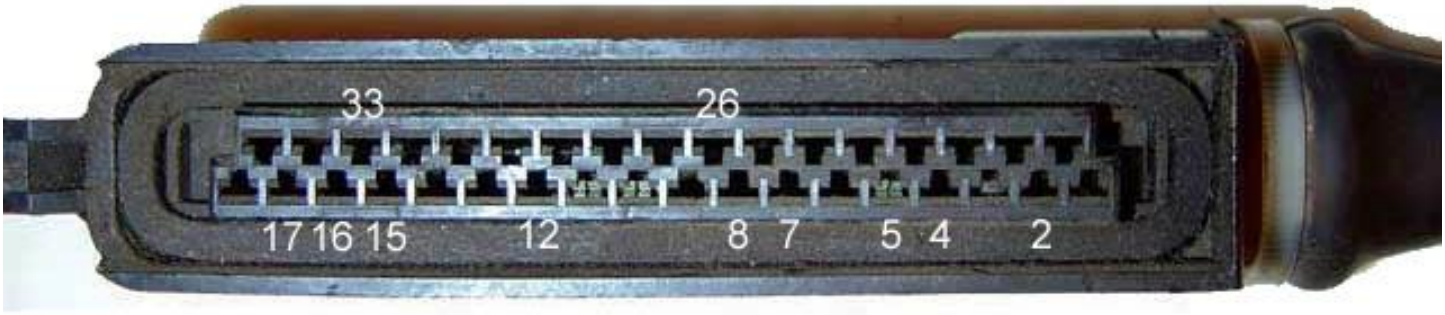
Result & conclusion: As can be seen in the Attempt #3 table, the readings from both meters are within specifications (aside from #4, which showed me the car had a too-lean mixture). The factory test port was indeed faulty by not providing good enough probe contact, which can be seen in the photo below.

* Update 2024: The insulated spade terminals have been replaced with a male EV1 connector, and a female EV1 was spliced into DVOM test leads for quick-connect testing. Refer back to page 6 for details.

* * Remember, **you** are responsible for working on **your** car; Cabby-Info.com, KamzKreationz, VAG, VWoA, or anyone else are not responsible if **anything** goes wrong while **you** are working on, in and under **your** car!
Use this information at your own risk!* *

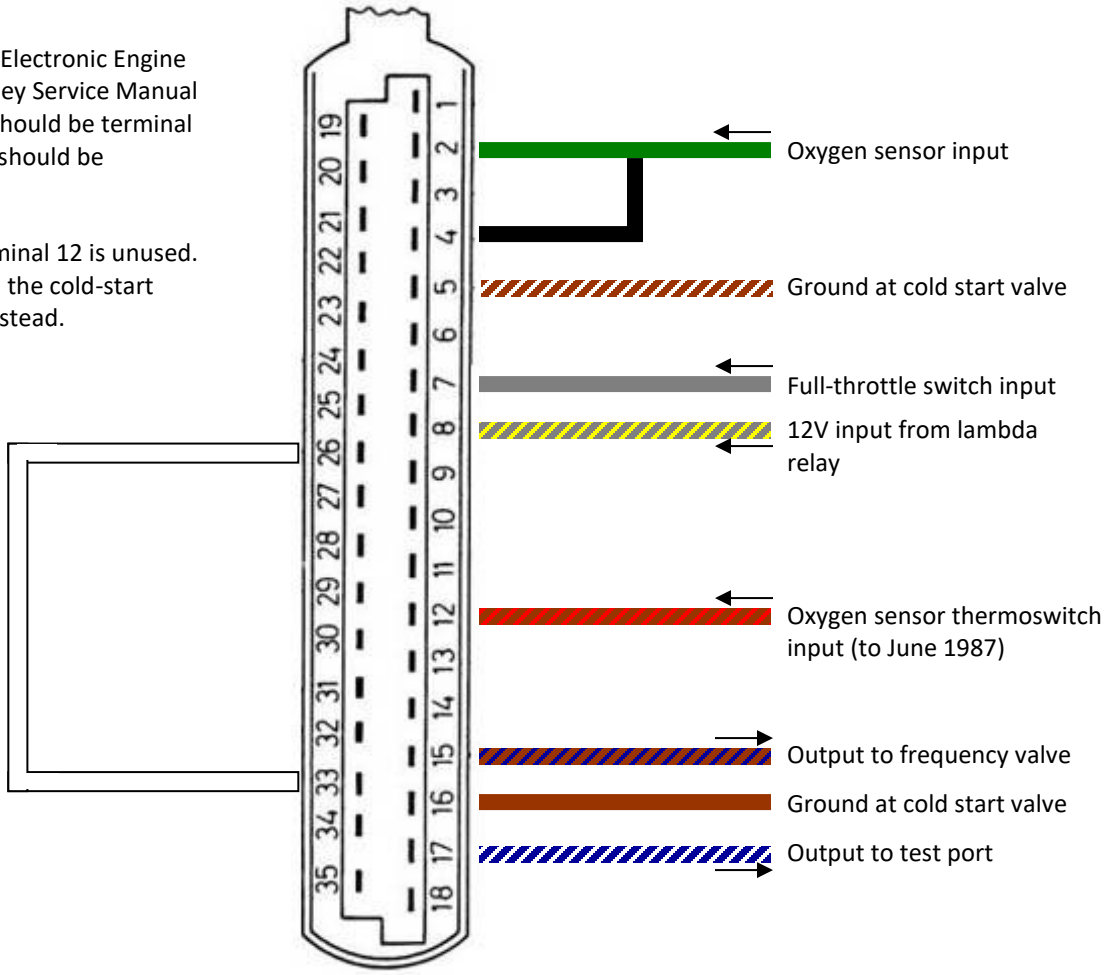
K-Jetronic Lambda Controller Pin-outs





NOTE: The July 1987 to 1989 Electronic Engine Controls diagram in the Bentley Service Manual has two errors: Terminal 21 should be terminal 15; wire color of terminal 17 should be blue/white, as shown here.

NOTE: July 1987 onward, terminal 12 is unused. The O2 thermoswitch goes to the cold-start (running) enrichment relay instead.


Oxygen sensor input
Ground at cold start valve
Full-throttle switch input
12V input from lambda relay
Oxygen sensor thermoswitch input (to June 1987)
Output to frequency valve
Ground at cold start valve
Output to test port